A FIRE ECOLOGY STUDY OF A SIERRA NEVADA FOOTHILL BASALTIC MESA GRASSLAND

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ABSTRACT

In late September 1994, a lightning fire burned a portion of the annual grassland on a Sierra Nevada foothill, basaltic mesa known as McKenzie Table located approximately 28 km northeast of Fresno, California. Permanent 1-m^2 quadrats were established in burned and unburned plots to determine the effect of fire on the plant-species composition of McKenzie Table. Data were gathered between February and June 1995. *Vulpia microstachys* sensu lato, a native annual grass, had the highest relative density for both the unburned and the burned plots with 14.14% and 11.81%, respectively. Using percent cover as a measure of dominance, a one-way ANOVA revealed significant differences in dominance between the burned and unburned plots; *Blennosperma nanum* var. *nanum* ($P < 0.05$), *Brodiaea terrestris* ssp. *kernensis* ($P < 0.01$), *Crassula connata* ($P < 0.01$), *Lasthenia californica* ($P < 0.01$), *Montia fontana* ($P < 0.01$), *Navarretia tagetina* ($P < 0.01$), *Triphysaria eriantha* ssp. *eriantha* ($P < 0.01$), and *Trifolium variegatum* ($P < 0.01$) had significantly greater dominance values for the burned plot. *Hypochaeris glabra* ($P < 0.01$) had significantly greater dominance values for the unburned plot. The unburned plot (36 native taxa) had 12 more native taxa than the burned plot (24 native taxa), but none had significantly different dominance values. In a comparison of species composition, the burned plot had higher percentages of native species. For native species, the Shannon-Wiener index of diversity (H′) is significantly greater ($P < 0.01$) for the burned plot ($H' = 5.63$) compared to the unburned plot ($H' = 3.90$). One season of results indicate that burning in the summer or fall may reduce non-native species, such as *Hypochaeris glabra,* and increase native-species diversity on McKenzie Table.

In late September 1994, a lightning fire burned 28 ha of annual grassland on top of a Sierra Nevada foothill, basaltic mesa called McKenzie Table (Fig. 1). This study was undertaken to determine if fire alters species composition and plant diversity in the annual grassland on McKenzie Table. Heady (1972) found that the composition and production of California annual grassland varies greatly during the seasons and from year to year. Seasonal changes result in fewer plants per unit area as the optimum growing climate wanes as summer progresses (Biswell and Graham 1956; Heady 1958). Yearly environmental changes may result in large shifts in grassland composition (Bentley and Talbot 1951; Heady 1961). Dominance may change yearly from grasses to forbs (Heady 1972). Fire alters the species composition within annual grasslands and the forage value for cattle (Graham 1956; Larson and Duncan 1982). The results of this study may have implications as to the use of fire to manage the annual grassland on McKenzie Table.

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FIG. 1. McKenzie Table (Photo taken 1.8 km southeast of the mesa).

Study Site and Methods

McKenzie Table is one of a series of basaltic-table mesas in eastern Fresno County, California, collectively known as Table Mountain (Fig. 2). Table Mountain is located 28 km northeast of Fresno and ranges in elevation from 518–591 m. At an elevation of 171 m, the San Joaquin River/Millerton Lake divides Table Mountain from other mesas north of the river in Madera County. The Table Mountain formation is Tertiary volcanic (basalt) formed when erosion exposed a historic San Joaquin River canyon lava flow (Division of Mines & Geology 1967). The mesa top is primarily annual grassland on shallow, moderately permeable, rocky soil of the Hideaway Series (United States Department of Agriculture 1971). McKenzie Table has numerous clumps of *Quercus douglasii* Hook. & Arn. and *Pinus sabiniana* Douglas in areas of the mesa top that have developed deeper soils. Several small vernal pools occur mostly in the northern portion of McKenzie Table. The rare *Castilleja compestris* (Benth.) Chuang & Heckard ssp. *succulenta* (Hoover) Chuang & Heckard and *Gratiola heterosepala* H. Mason & Bacigal. are known to occur in these pools (Rarefind 1995). Due to its physiography, Table Mountain tends to receive less fog during the winter than the surrounding foothills and San Joaquin Valley (personal observation from 1992 to 1995). The October 1994 to June 1995 precipitation in the central Sierra Nevada foothills was approximately 100 cm (recorded by author near Table Mountain, in the town of Auberry, at an elevation of 518 m). This was 61% above the 62 cm annual average precipitation for Auberry (United States Department of Ag-

FIG. 2. McKenzie Table is located 28 km northeast of Fresno, California, in the foothills of the Sierra Nevada Range.

riculture 1971). Cattle grazed McKenzie Table in the past, but managed grazing was discontinued on the mesa top in 1991 (Chuck Peck personal communication 1996).

In February 1995, plots were established on McKenzie Table (37°01′21″N, 119°35′59″W; T10S R22E, S31, NW ¼), at an elevation of 550 m. Two adjacent 5041 m^2 study plots, one in the burned area and the other outside the burned area, were stratified from the rest of the table grassland based on geomorphic uniformity and the spread pattern of the burn. Twenty-five 1-m^2 quadrats were randomly established on both plots using transect grids. Opposite corners of the quadrats were permanently established with wooden stakes. Data were collected from the 50 quadrats on 24 February, 17 March, 7 April, 28 April, 19 May, and 11 June 1995. Density (number of rooted individuals) and percent cover (dominance) were recorded, as class values ranging from 0–4, for each observed taxa within the quadrats. The density classes were as follows: 0 = 0 individuals, 1 = 1–10 individuals, 2 = 11–50 individuals, 3 = 51–100 individuals, and 4 = >100 individuals. The percent-cover classes were as follows: 0 = 0% coverage, 1 = 1–10% coverage, 2 = 11–50% coverage, 3 = 51–75% coverage, and 4 = 76–100% coverage. Cover data were also recorded for exposed rock found in a quadrat. Density and percent-cover data were converted to class medians and compared using one-way ANOVA (Sokal and Rohlf 1981). The Shannon-Wiener index of diversity (H′) was calculated for both plots from native-species data (Barbour et al. 1980). H′ values were calculated for all 50 quadrats to determine significance, using one-way ANOVA, between the unburned and burned plots. Only native species were used to calculate H′ because non-native species could have contributed to larger H′ values, thus indicating a more diverse ecosystem. The diversity of native species is relevant to management objectives that land managers use to measure the health of an ecosystem.

RESULTS

Relative density, average cover (mean ± 1 SE), and frequency for each of the 50 taxa recorded from the study plots are presented in Table 1. Although *Crassula connata* (Ruíz Lopez & Pavón) A. Berger had similar relative density values for both plots, it was significantly dominant ($P < 0.01$) in the burned plot. *Hypochaeris glabra* L., *Vulpia bromoides* (L.) S. F. Gray, and *Erodium brachycarpum* (Godron) Thell. were the most prevalent, invasive, non-native species in the unburned plot. In the unburned plot, *Hypochaeris glabra* was significantly dominant ($P < 0.01$); in fact, it had 68% frequency in the unburned plot compared to 4% frequency in the burned plot. Plot frequencies of 100% on the burned plot were common for taxa with significantly greater dominance values. The number of recorded native taxa (36) was 12 greater on the unburned plot than the burned plot (24), but those taxa were not significantly dominant and the frequencies were generally low. Table 2 illustrates that native species relative density and percentage of recorded taxa were greater for the burned plot.

TABLE 1. RELATIVE DENSITY, AVERAGE COVER (MEAN ± 1 SE), AND FREQUENCY OF EACH OBSERVED SPECIES ON THE UNBURNED AND BURNED PLOTS. One-way ANOVA values of average cover variation between unburned and burned plots indicated as significant (*, $P < 0.05$; **, $P < 0.01$).

Species	Relative density		Average cover		Frequency	
	Unburned %	Burned %	Unburned %	Burned %	Unburned %	Burned %
Native	—	—	—	—	—	—
Agrostis microphylla Steudel.	0.10	0.49	0.40 ± 0.28	2.84 ± 1.68	8	16
Amsinckia eastwoodiae J. F. Macbr.	0.05	0	1.22 ± 1.22	0	4	0
Amsinckia menziesii (Lehm.) Nelson & J. F. Macbr. var. *menziesii*	0.05	0	0.20 ± 0.20	0	4	0
Blennosperma nanum (Hook.) S. F. Blake var. *nanum*	0.10	1.56	0.40 ± 0.28*	7.28 ± 2.11*	8	64
Brodiaea terrestris Kellogg ssp. *kernensis* (Hoover) T. Niehaus	2.97	3.61	7.26 ± 1.79**	25.40 ± 2.08**	84	100
Castilleja attenuata (A. Gray) Chuang & Heckard	0.14	0	0.60 ± 0.33	0	12	0
Calandrinia ciliata (Ruíz Lopez & Pavón) DC.	0.10	0	0.40 ± 0.28	0	8	0
Chlorogalum angustifolium Kellogg	0.24	0.33	1.00 ± 0.41	2.40 ± 0.51	20	48
Chlorogalum pomeridianum Kunth	0	0.05	0	0.20 ± 0.20	0	4
Clarkia purpurea (Curtis) Nelson & J. F. Macbr. ssp. *quadrivulnera* (Douglas) Harlan Lewis & M. Lewis	0.05	0	0.20 ± 0.20	0	4	0
Crassula connata (Ruíz Lopez & Pavón) A. Berger	10.27	11.39	9.92 ± 2.39**	25.00 ± 2.25**	76	92
Deschampsia danthonioides (Trin.) Munro	2.21	1.40	4.46 ± 1.99	5.86 ± 1.91	28	56
Dodecatheon clevelandii E. Greene ssp. *patulum* (E. Greene) H. J. Thompson	0	0.03	0	0.20 ± 0.20	0	4
Eschscholzia lobbii E. Greene	1.20	0	2.42 ± 1.24	0	24	0
Holocarpha heermannii (E. Greene) Keck	0.27	0	1.22 ± 1.22	0	4	0
Juncus bufonius L. sensu lato	1.21	1.16	5.48 ± 2.25	6.30 ± 2.47	28	24
Lasthenia californica Lindley	4.04	9.34	15.10 ± 3.37**	38.58 ± 3.26**	72	100

TABLE 1. CONTINUED.

Species	Relative density		Average cover		Frequency	
	Unburned %	Burned %	Unburned %	Burned %	Unburned %	Burned %
Layia fremontii (Torrey & A. Gray) A. Gray	0.27	0	1.22 ± 1.22	0	4	0
Lepidium nitidum Torrey & A. Gray var. *nitidum*	9.95	7.86	15.42 ± 2.74	22.96 ± 2.47	84	92
Lithophragma bolanderi A. Gray	0.27	0	1.22 ± 1.22	0	4	0
Lupinus bicolor Lindley	0.14	0	0.60 ± 0.33	0	12	0
Minuartia californica (A. Gray) Mattf.	0.05	0.45	0.20 ± 0.20	2.42 ± 1.24	4	28
Minuartia douglasii (Torrey & A. Gray) Mattf.	0.05	0	0.20 ± 0.20	0	4	0
Montia fontana L.	2.71	7.61	5.46 ± 1.94**	23.64 ± 2.90**	48	100
Navarretia tagetina E. Greene	1.88	5.79	3.42 ± 1.23**	26.70 ± 2.56**	48	100
Parvisedum congdonii (Eastw.) R. T. Clausen	1.80	0.03	2.64 ± 1.68	0.20 ± 0.20	12	4
Parvisedum pumilum (Benth.) R. T. Clausen	0	0.21	0	0.60 ± 0.33	0	12
Phalaris arundinacea L.	0.05	0	0.20 ± 0.20	0	4	0
Plantago erecta E. Morris	5.87	8.21	12.06 ± 3.40	23.98 ± 2.37	52	92
Poa secunda J. S. Presl ssp. *secunda*	0.10	0	0.40 ± 0.28	0	8	0
Psilocarphus brevissimus Nutt. var. *brevissimus*	0.27	0	1.22 ± 1.22	0	4	0
Selaginella hansenii Hieron.	0.05	0	0.20 ± 0.20	0	4	0
Sidalcea calycosa M. E. Jones ssp. *calycosa*	0.29	0.20	1.20 ± 0.43	1.40 ± 0.46	24	28
Trifolium depauperatum Desv. var. *amplectens* (Torrey & A. Gray) L. F. McDermott	3.09	1.91	8.90 ± 2.24	12.76 ± 2.49	76	92
Trifolium variegatum Nutt.	2.93	5.59	6.48 ± 2.18**	27.72 ± 2.40**	48	100
Trifolium willdenovii Sprengel	2.01	1.70	7.30 ± 2.40	9.54 ± 2.69	56	48
Triphysaria eriantha (Benth.) Chuang & Heckard ssp. *eriantha*	1.85	4.90	4.22 ± 1.19**	20.92 ± 2.61**	64	92
Triteleia hyacinthina (Lindley) E. Greene	5.20	3.97	19.90 ± 2.66	28.46 ± 1.41	92	100
Vulpia microstachys (Nutt.) Munro sensu lato	14.14	11.81	22.84 ± 3.13	30.86 ± 2.47	92	96

Table 1. Continued.

Species	Relative density		Average cover		Frequency	
	Unburned %	Burned %	Unburned %	Burned %	Unburned %	Burned %
Non-native	—	—	—	—	—	—
Avena barbata Link	0.10	0.06	0.40 ± 0.28	0.40 ± 0.28	8	8
Bromus hordeaceus L.	3.30	0.44	8.20 ± 3.18	1.62 ± 1.23	36	12
Bromus diandrus Roth	0.63	0	1.82 ± 1.24	0	16	0
Cerastium glomeratum Thuill.	0.05	0	0.20 ± 0.20	0	4	0
Erodium brachycarpum (Godron) Thell.	10.18	5.34	22.62 ± 2.98	21.32 ± 2.49	100	100
Gnaphalium luteo-album L.	0.05	0	0.20 ± 0.20	0	4	0
Hordeum murinum L. ssp. *leporinum* (Link) *Arcang.*	0.36	0	1.62 ± 1.23	0	12	0
Hypochaeris glabra L.	2.95	0.03	10.54 ± 2.57**	0.20 ± 0.20**	68	4
Sonchus asper (L.) Hill ssp. *asper*	0.05	0	0.20 ± 0.20	0	4	0
Vulpia bromoides (L.) S. F. Gray	5.40	4.40	12.38 ± 2.80	13.58 ± 2.60	64	88
Vulpia myuros (L.) C. Gmelin sensu lato	0.85	0	2.84 ± 1.68	0	16	0
Exposed Rock	—	—	27.44 ± 1.69	31.80 ± 1.30	100	100
Total	99.89	99.87	—	—	—	—

TABLE 2. A DENSITY AND SPECIES PERCENT COMPOSITION COMPARISON OF NON-NATIVE TO NATIVE TAXA IN UNBURNED AND BURNED STUDY PLOTS.

	Unburned plot		Burned plot	
Species Type	Relative density %	Species composition % of 47 taxa	Relative density %	Species composition % of 29 taxa
Native Species	76	77	90	83
Non-native Species	24	23	10	17

The diversity results are as follows:

	Shannon-Wiener Diversity Index (H′)
Unburned plot	3.90
Burned plot	5.63*

* significantly greater (P<0.001)

The scale ranges from 0 (only 1 species) to 7 (very diverse ecosystem) or greater (Barbour et al. 1980).

Although *Agrostis microphylla* Steudel dominance was not significantly different between the unburned and burned plots, it was an important find since it was previously unknown from the Sierra Nevada (*York 104A* [JEPS]). Harvey (1993) describes the range of *Agrostis microphylla* in California as the southern North Coast Ranges and North, Central, and South Coast subregions.

DISCUSSION

The results of this study indicate that fire can significantly alter species composition and diversity in annual grasslands. Eight native annuals and a perennial, *Brodiaea terrestris* Kellogg ssp. *kernensis* (Hoover) T. Niehaus, had significant responses to the fire. The increased presence of *Blennosperma nanum* (Hook.) S. F. Blake var. *nanum, Lasthenia californica* Lindley, *Navarretia tagetina* E. Greene, and *Triphysaria eriantha* (Benth.) Chuang & Heckard ssp. *eriantha* during the growing season following the fire suggests that these species have seed that responds positively to fire scarification and/or the removal of the thatch coupled with the additional nutrients released by the fire stimulated germination and increased seedling survival. Fire removes the thatch barrier while providing a source of nutrient-rich ash which leads to enhanced growth of herbaceous plants (Barbour et al. 1993). The removal of thatch has more of an effect on diminutive species, such as *Crassula connata* and *Montia fontana* L., since these plants appear to require early contact with mineral soil to germinate and grow before conditions become intolerable due to competition and soil desiccation.

The significant increase in dominance of *Brodiaea terrestris* ssp. *kernensis* in the burned plot cannot be explained by an increased seed germination and survival rate. It takes more than one growing season for cormous plants, such as *Brodiaea terrestris* ssp. *kernensis,* to develop from seed to a reproductive adult. Since brodiaeas, like many geophytes, may remain dormant or only produce leaves and forego flowering as a response to environmental conditions (personal observation), there may have been just as many *Brodiaea terrestris* ssp. *kernensis* corms in both plots. The nutrient flush from the ash may have stimulated *Brodiaea terrestris* ssp. *kernensis* to flower in the burned plot.

Fire significantly reduced the non-native *Hypochaeris glabra* from the study area. *Hypochaeris glabra* is a prolific producer of small, far-ranging cypselae (personal observation). These diminutive cypselae become lodged in the organic layer making them more susceptible to fire. In comparison, *Erodium brachycarpum* was not affected by the fire. Larson and Duncan (1982) found that an annual-grassland fire, on the nearby San Joaquin Experimental Range in Madera County, had no effect on *Erodium botrys* (Cav.) Bertol. The seeds of *Erodium* spp. have a self-burial mechanism allowing the seeds to escape being damaged by fire (Young et al. 1975).

Having a significantly greater plant diversity one season after a burn is consistent with the results of a burn study in southern California chaparral (Keeley et al. 1981). The significant increase in diversity and in dominance of eight native annual plants, combined with the significant decrease in dominance of non-native *Hypochaeris glabra,* are all indications that fire maybe a useful tool to restore and maintain biodiversity on McKenzie Table. It is possible that the virtual extirpation of *Hypochaeris glabra* from the burned plot may have contributed to the increased plant diversity. Schierenbeck (1995) noted the potential impacts from non-native species as being a decreased biodiversity, changes to successional patterns, genetic contamination, and physical as well as functional changes to ecosystems. Future research should focus on the continued collection of data from my study plots to learn the effects of fire over the long-term and with varied frequency, and the effectiveness of other management methods, such as cattle, to maintain biodiversity.

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